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ABSTRACT

The relationship between perceptual structure and individual differences in cognitive ability was studied through a computerized inductive reasoning task performed by 100 college undergraduates at Cleveland State University (Ohio). Measures included two psychometric tests and a set of four computerized cognitive tasks. Two components of perceptual structure were defined and measured: intrastimulus, and interstimulus dimensional structure. Intrastimulus (within stimulus) structure was a measure of individual stimulus complexity. Interstimulus structure was a measure of relationships between two or more multidimensional stimuli. Within interstimulus structure, two separate component structures were identified: amount and form. Amount was the quantitative component, a measure of the information load of the matrix. Form was the relational component, and reflected a level of predictability among stimulus dimensions in the matrix. Results indicate that changing dimensional structure between stimuli was an important factor in the prediction of individual differences in intelligence. Separate parameters of interstimulus form and amount were identified as independent predictors of individual differences in ability; interstimulus form was most highly related to individual differences in general cognitive ability. Results support the structural model of F. L. Royer (1978) and are consistent with interpretations of C. E. Spearman's (1923) qualitative model of mental ability as a model of perceptual processing. Two tables, three figures, and one appendix amplify the study. There is a 60-item bibliography. (Author/SLD)

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The Relationship between Perceptual Structure and Individual Differences in Performance
on an Inductive Reasoning Task

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Running Head: PERCEPTUAL STRUCTURE AND INDIVIDUAL DIFFERENCES

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THE RELATIONSHIP BETWEEN PERCEPTUAL STRUCTURE AND INDIVIDUAL DIFFERENCES IN PERFORMANCE ON AN INDUCTIVE REASONING TASK

Abstract

It is the intelligent person who is often able to impose order on what might appear to be unrelated events. It is this ability to recognize and successfully utilize structure that helps distinguish the intelligent from the unintelligent person (Royer, 1978). Spearman (1923) called it the 'ability to educe relations between objects'. Thurstone (1931) called it 'inductive reasoning'. Perceptual processes played a crucial role in Spearman's (1923) model of intelligence. The purpose of the current research was to systematically investigate the relationship between perceptual structure and individual differences in cognitive ability. A computerized study was conducted at Cleveland State University with 100 college undergraduates. Two components of perceptual structure were defined and measured: intrastimulus and interstimulus dimensional structure. Intrastimulus (within stimulus) structure is a measure of individual stimulus complexity. Interstimulus structure is a measure of relationships between two or more multidimensional stimuli. Within interstimulus structure, two separate components structure were also defined: amount and form. Amount was the quantitative component of interstimulus structure; form was the relational component. Amount was a measure of the information load of the matrix. Form reflected the level of predictability among stimulus dimensions in the matrix. Results indicated that changing dimensional structure between stimuli was an important factor in the prediction of individual differences in intelligence. Separate parameters of interstimulus form and amount were identified as independent predictors of individual differences in ability. Interstimulus form was the most highly related to individual differences in general cognitive ability. Royer's (1978) structural model of individual differences was supported. Results were consistent with interpretations of Spearman's (1923) qualitative model of mental ability as a model of perceptual processing.

THE RELATIONSHIP BETWEEN PERCEPTUAL STRUCTURE AND INDIVIDUAL DIFFERENCES IN PERFORMANCE ON AN INDUCTIVE REASONING TASK

Purpose

The general purpose of the current study was to refine a previously constructed experimental matrix task (Andrist & Detterman, 1990) in order to independently define and reliably measure specific parameters of dimensional structure which make matrix task performance an important predictor of individual differences in cognitive ability. Parameters of dimensional structure within stimuli (intra-stimulus structure) and between stimuli (inter-stimulus structure) in a 3x3 matrix of novel visual stimuli were defined. The importance of each parameter in the predictability of individual differences in cognitive ability was tested. It was argued, following Rumelhardt and Abrahamson (1973), that tasks traditionally thought of in terms of 'higher order' mental processes can be conceptualized in terms of changing structural relationships within the task. The current research was based on a perceptual model of relationships between stimuli (Whitman & Garner, 1962; Royer, 1978). Results are linked to Spearman's (1923) processing model of intelligence.

Background

It is the intelligent person who is often able to impose order on what might appear to be unrelated events. It is this ability to recognize and successfully utilize structure that helps distinguish the intelligent from the unintelligent person (Royer, 1978). Spearman (1923) called it the 'ability to deduce relations between objects'. Thurstone (1931) called it 'inductive reasoning'. Performance on inductive reasoning tasks has been shown to be highly correlated with intelligence. In fact, inductive reasoning has been described as the cornerstone of intelligence in many current theories of intelligence (e.g., Pellegrino, 1985; Sternberg & Garner, 1982).

Perceptual processes played a crucial role in Spearman's (1923) model of intelligence. Consistent with this notion, it has been argued that the ability to perceive stimulus structure should be highly related to individual differences in intelligence (Royer, 1978). But the relationship between individual differences in intelligence and individual differences in the ability to perceive stimulus structure is not clearly understood. For example, results from studies investigating the relationship between measures of perceptual structure and individual differences in intelligence have not consistently supported a relationship between intelligence and the

ability to use stimulus structure (e.g., Silverman, 1975). Even studies which have identified a relationship between measures of perceptual structure and individual differences in intelligence have identified differences in the encoding time of stimuli but not patterns of encoding (e.g., Caruso & Detterman, 1983). The lack of a relationship between intelligence and patterns of stimulus encoding brings the role of stimulus structure in the prediction of individual differences into question.

It will be argued that in order to better understand the relationship between individual differences in intelligence and perceptual structure, a distinction between two types of stimulus structure needs to be made: intrastimulus and interstimulus structure. Intrastimulus structure refers to individual stimulus complexity. Individual stimulus structure is closely aligned with information theory and has been shown to affect information load and encoding of individual stimulus items (e.g., Attneave, 1955; Clement & Varnadoe, 1967; Garner, 1962; 1974). Individual stimulus complexity corresponds to Spearman's 'apprehension of fundamentals' or the encoding of individual stimulus items. Interstimulus structure, on the other hand, is an index of the structure between stimuli in a multidimensional set.

The lack of a relationship between intelligence and patterns of stimulus encoding may be better understood by examining studies according to the type of perceptual structure (intrastimulus versus interstimulus) being studied. The relationship between intelligence and perceptual structure has generally been investigated by manipulating the role of individual stimulus complexity or intrastimulus structure. These studies have investigated a range of both quantitative and structural perceptual measures which reflect the amount and form of information in individual stimuli. Both quantitative and structural aspects of intrastimulus information have been shown to independently influence the encoding difficulty of individual stimuli (e.g., Chipman, 1977; Garner, 1962; Ichikawa, 1985; Kahana, 1989; Royer, 1966). Intrastimulus parameters have been shown to be sensitive to individual differences in encoding time but not patterns of encoding (e.g., Caruso & Detterman, 1983).

The relationship between interstimulus perceptual structure and individual differences in intelligence, on the other hand, has not generally been explored as such. Although studies which measure individual differences in performance as a function of relationships between stimuli, i.e., categorization and reasoning studies, have found a strong relationship between individual differences and patterns of performance,

these studies have most often explained performance in terms of strategic and/or control processes (e.g., Belmont & Butterfield, 1971; Borkowski, Carr, & Pressley, 1987; Brown & Campione, 1984; Sternberg & Garner, 1982). The role of interstimulus perceptual structure in studies of individual differences has been almost totally ignored. But it is precisely interstimulus structure or the relationships between stimuli which Spearman first identified as a crucial component in the study of individual differences (Spearman, 1923). Before individual differences in performance can be attributed to higher order conceptual and control processes, the role of changing perceptual structure needs to be better understood.

Spearman defined the 'eduction of relations and correlates' as the perception of the relationship between two fundaments or items. In current studies of inductive reasoning, the eduction of relations and correlates has generally been defined in terms transformational rules (e.g., Evans, 1968; Mulholland et al., 1980; Raven, 1948; Sternberg, 1977). On the most basic level, these rules can be thought of as a series of similarity judgements based on the number of shared dimensions between stimuli in multi-dimensional space (e.g., Holyoak, 1984; Royer, 1978; Rumelhardt & Abrahamson, 1973; Smith, 1989; Whitman & Garner, 1962).

The description of transformational rules in terms of dimensional relationships provides a logical transition between conceptual and perceptual structure. Individual differences in the ability to perceive simple dimensional relationships is a fundamental process which has been studied by many authors in the areas of attention, perception, and cognition (e.g., Gibson, 1969; House, 1979; Tighe & Tighe, 1979; Tversky, 1977; Zeaman, 1978). In fact, the ability to recognize and use simple dimensional relationships is often cited as the primary building block for concept formation, categorization, and reasoning (e.g., Medin, 1983; Offenbach, 1983; Smith, 1989; Rumelhardt, 1989).

The relationships between elements in a set, or interstimulus structure, can also be thought of in terms of two independent components which reflect the amount and form of perceptual structure between stimuli, respectively. The amount of structure is determined by the size of the subset in relationship to the total or implied set of elements. The amount of structure is a function of the number of dimensions which change across the subset of stimuli. The number of changing dimensions or the uncertainty level of the subset of stimuli. The form of interstimulus structure is a function of the level of predictability or correlation between changing dimensions.

Numerous similarity or classification indices have been proposed in order to describe the dimensional relationship between multidimensional objects (e.g., Rumelhardt & Abrahamson, 1973; Tversky, 1977; Whitman & Garner, 1962). These indices can be divided into two broad classes. The first class consists of indices based on the measurement of continuous attributes or dimensions, e.g., similarity scaling or distance measures. These measures have been used extensively in the classic psychophysical literature but only rarely in the concept learning literature (e.g., Rumelhardt & Abrahamson, 1973). The second type of index is based on the number of discrete features or dimensions shared by two or more objects (e.g., Whitman & Garner, 1962; Tversky, 1977). These indices have been used extensively in the classification and concept learning literature (e.g., Medin, 1983; Shepp & Swartz, 1976; Smith & Kemler, 1977), most often in terms of feature analysis (dichotomous attributes that are either present or absent) rather than dimensional analyses (attributes with multiple levels).

The current study is based on the role of changing relationships among dimensions in an inductive reasoning task. The index of dimensional structure used in the current study is based on the number of discrete dimensions which are related in a simple contingent manner. This correlational index of similarity was developed by Whitman and Garner (1962) in order to quantify the dimensional structure between two or more multidimensional stimuli and was subsequently termed 'correlational structure'. This index reflects the form or redundancy of perceptual structure between stimuli while controlling the information load or amount of perceptual structure within individual stimuli.

Applying the index of dimensional structure proposed by Whitman and Garner (1962), inductive processes such as categorization or rule formulation can be defined in terms of the number of correlated or simple contingent dimensional relationships (Royer, 1978; 1981). Royer tested the relationship between the level of correlational structure in a 3x3 matrix of multidimensional stimuli and both time and number correct on the matrix task. Royer found that the degree of correlation between both shared dimensions and spatial position of the stimuli predicted performance on the matrix task. The predictability or correlational structure among stimuli was an index of matrix difficulty. The less predictable relationships among dimensions were, the more difficult the matrix became to solve.

Research Proposal

The current study had three specific aims: 1) To operationally define and measure two independent parameters which represented quantitative and relational components of changing dimensional relationships between stimuli in a 3x3 computerized matrix task, i.e., interstimulus amount and form, respectively, 2) To test the relationship between interstimulus amount and form, and individual differences in performance on measures of reasoning and standardized achievement, and 3) To test the combined influence of interstimulus and intrastimulus structure on individual differences in matrix task performance.

Method

Subjects

Subjects were one-hundred and nine subjects students attending classes at Cleveland State University. Participation was part of an optional Psychology course requirement. Six subjects had incomplete data on the experimental task: three due to technical difficulties; three failed to show-up for the second testing session. Three subjects with complete data were not included in the current analysis due to a combination of no sleep and random response on the second session (judged a priori).

Data for one-hundred students between the ages of 18 and 42 ($M = 23$, $SD = 5.9$) years were included in the current analyses. The group was 27.5 percent male and 67.5 percent white with a mean education level of 13.7 ($SD = 1.98$) years. Students scored at the national average on the Composite Score of the American College Test (ACT) with a mean of 18 ($SD = 6.7$) and slightly above average on the Standardized Raven's Progressive Matrix Test (Raven, 1958) with a mean of 47 ($SD = 6.4$) correct as compared to their normative age sample of 44 correct.

Materials

Measures included two psychometric tests and a set of four computerized cognitive tasks. Computerized tasks included both elementary cognitive tasks and an adapted experimental matrix task which manipulated levels of perceptual structure.

Psychometric tests. Psychometric tests included the Raven's Standard Progressive Matrices (SPM; Raven, 1958) and the composite score from the American College Test (ACT). The SPM is a standardized paper-pencil test of inductive reasoning tasks which has consistently been shown to be highly 'g'

loaded (e.g., Paul, 1985; Jensen, 1987). The Raven's Progressive Matrices (RPM) were designed specifically to test 'the apprehension of fundamentals, and the eduction of relations and correlates' (Raven, 1948). The ACT composite is a college entrance exam used to access general academic ability. The ACT was only available for 63 of the 100 students tested.

Computerized tasks. Computerized tasks included both a match-to-sample test and an experimental matrix task. The match-to-sample task was designed to measure response selection and execution times for the exemplar rows of the experimental task. The experimental matrix task was designed to measure performance as a function of changing levels of perceptual structure. Stimuli were novel perceptual stimuli which looked like 4x4 grids with some of the squares filled.

Adapted experimental matrix task. In order to systematically test the relationship between parameters of perceptual structure and individual differences in mental ability, the original computerized matrix task was adapted for the current study. The adapted matrix task further defined and tested parameters of perceptual structure as follows: 1) Separate components of interstimulus structure were defined by independently manipulating the amount (number of dimensions which varied in the matrix) and form (level of correlation between dimensions), and 2) Individual stimulus complexity (intra-stimulus complexity) was also manipulated in the adapted matrix task by including both simple and complex sets of stimuli equally represented across all levels of interstimulus (matrix) structure.

Elementary cognitive tasks. Elementary cognitive tasks included three tasks from the Cognitive Abilities Test (CAT; Detterman, 1988) which were designed to test basic cognitive processes. The three elementary tasks included in the current study were: match-to-sample (MS), tachistoscopic threshold (TT), and learning (LR). The MS task measured basic parameters of encoding, discrimination, and response selection/execution. The MS task for the current study was adapted so that each trial was composed of an exemplar row used in the first half of the experimental matrix task. The TT and LR tasks were included in order to test the relationship between parameters of perceptual structure and individual differences in both time needed to judge if two stimuli were the same or different (discrimination time) and ability to recall the position of stimuli, respectively. The LR and TT tasks used the standard set of novel perceptual stimuli developed for CAT (Cognitive Abilities Tests; Detterman, 1988).

Apparatus

All computerized tasks were administered on an AT-compatible microcomputer with an IBM Enhanced Graphics Adapter (EGA). A high resolution color monitor was used to present novel perceptual stimuli. The computer monitor was positioned at a 30 degree angle from horizontal with the lower edge of the screen placed at a height of approximately 65 cm.. Mean viewing distance was approximately 53 cm. All stimuli were 4x4 grids of rectangular cells with some of the cells filled. Each stimulus measured approximately 3 cm X 2.5 cm (64 pixels X 56 pixels).

Computer monitors were fitted with a Personal Touch touchscreen. Cognitive tasks had the image of a spacebar positioned in the bottom-center of the display. The bar served as a response device for trial initiation. Feedback for correct responses on all computerized tasks was a two tone beep (1000 HZ/100 msec; 1500 HZ/200 msec). Feedback for incorrect responses was a two tone buzz (100 HZ/200 msec; 50 HZ/300 msec).

Design

Novel perceptual stimuli were identified as optimal for the current study. Novel perceptual stimuli allow better control of both information load and influences of previous learning and memory. Stimuli were 4x4 grids which varied in the number and position of squares filled. Individual stimuli were constructed from a set of three dimensions which consisted of three levels each as follows: number of cells filled (4, 6, & 8), cohesiveness (# of adjacencies), and degree of rotation (0, 90, & 180) for each stimulus.

Two levels of intrastimulus (within stimulus) complexity and twelve levels of interstimulus (between stimulus) complexity were tested in the current study. All manipulations of perceptual structure were defined by three object dimensions: number of cells filled, rotation, and adjacencies. Spatial position of stimuli in the matrix (correlated or uncorrelated with y-axis) was manipulated as a fourth dimension of interstimulus form.

Intrastimulus structure

In order to choose two sets of stimuli which represented simple and complex levels of intrastimulus structure, respectively, an initial set of 27 items was generated by the experimenter which varied in number (4,6,8) and adjacency of pattern components. The items were then put together in matrix form and

rated by 27 students in the Psychology Department at Case Western Reserve University. Students were asked to rate the matrices on a scale of one to five with one being the easiest and five being the hardest. Several students had difficulty using the entire range of numbers, therefore a mean rating was computed using z-scores standardized on each rater's own distribution of ratings. Three stimuli with low mean ratings were chosen as the simple set; the three stimuli with high mean ratings were chosen as the complex set. A t-test demonstrated that ratings on the two sets were significantly different, $t = 8.06$, $p < .001$. Both the initial set of 27 matrices and the simple and complex sets of stimuli chosen for the current study are presented in Appendices A and B, respectively.

The SCP (Kahana, 1988) was used to calculate measures of intrastimulus structure for the simple and complex set. Symmetry was measured by calculating the number of elements generated if the stimulus was rotated and reflected (ESS) and through a measure of sub-symmetry. Adjacencies were calculated by taking the mean number of horizontal and/or vertical adjacencies. Diagonal adjacencies were not included in the calculations. Changes in adjacencies and symmetry have been shown to independently affect the information load or complexity of individual stimuli (Chipman, 1977; Ichikawa, 1985). Table 1 shows the mean intrastimulus structure values for the simple and complex stimulus sets chosen for the current study.

Insert Table 1 about here

Interstimulus structure

Two separate components of interstimulus dimensional structure (amount and form) were independently defined and manipulated. The amount of interstimulus structure was defined as the number of changing dimensions in each 3×3 matrix. The form of interstimulus structure was determined by the number of simple contingent dimensional relationships in the matrix, i.e., the predictability or correlation among matrix dimensions. Amount was the quantitative index of the matrix. Form was the structural index. Amount, as defined, sets a lower limit on the form of interstimulus dimensional structure.

The 12 levels of interstimulus structure represented an unbalanced manipulation of quantity X form (Garner, 1974; Royer, 1978). Quantity was represented by the number of object dimensions (1 to 3) which

varied in the total matrix. Object dimensions included: number of cells filled, adjacencies, and rotation of the pattern. This quantitative measure of interstimulus structure was defined as the amount of structure present in the matrix. The form of the matrix was represented by the level of correlation between both spatial and object dimensions. Spatial structure refers to the ordered (correlated with the y-axis) versus latin square (uncorrelated with the y-axis) arrangement of dimensions in the matrix. Object structure refers to the level of correlation between dimensions or the number of dimensions (3-0) which are related to each other in a simple contingent manner. Levels of interstimulus form ranged from simple contingent structure (3 dimensions correlated) to complex structure (0 dimensions correlated). The 12 levels of interstimulus structure are presented in Figure 1.

Insert Figure 1 about here

Stimuli from the two levels of stimulus complexity (simple/complex) were randomly tested 5 times within every level of interstimulus complexity, generating 10 trials for each of the 12 levels. Levels of interstimulus complexity (simple/complex) were tested in increasing order of difficulty beginning with the lowest level of amount and simplest, most highly correlated level of form, respectively increasing in difficulty to the highest amount of form and most complex level of structure.

The stimulus pattern remained constant within each matrix problem tested. Mean stimulus complexity of individual matrix problems, i.e., number of cells filled, number of adjacencies, symmetry, and redundancy, did not differ across the 12 levels of interstimulus structure. Target positions for the row of response choices were chosen randomly with the constraint that targets appear in all six positions an equal number of times.

Procedure

Six measures were included in the current study: the American College Test (ACT), the Standard Progressive Matrices Test (SPM; Raven, 1958), a computerized matrix task designed for the current study, and three computerized tasks which measured basic cognitive abilities (CAT; Detterman, 1988). The ACT was administered prior to college admission. ACT composite scores were obtained from University files. All other tests were administered to students by the author. After initial efforts to administer the SPM in group format

proved inefficient, due to low numbers of subjects in group sessions, all testing was conducted in two individual sessions as described below. Each session lasted an average of 1.5 hours. No differences were found between the scores of students who received the SPM in group versus individual sessions. Total time for each subject to complete the study varied between 2.5 to 4 hours.

Procedures for each of the five measures are described below. Following descriptions of individual task procedures, the structure of the first and second testing sessions are described.

Standard Progressive Matrices (SPM)

The SPM is a 60 trial paper-pencil test consisting of a series of 3x3 matrices with the bottom right hand corner piece missing. A row of eight exemplars numbered from 1 to 8 appear at the bottom of each page. Students were told to fill in the piece of the missing pattern. Each student indicated the number of the item which best completed the pattern by marking it on the answer sheet provided. Standard SPM test booklets were used. No practice items were administered.

Each trial consisted of a 3x3 matrix of stimuli with the bottom right hand corner item missing. Six exemplars appeared in a row at the bottom of the computer screen. The subject's task was to choose the item which best completed the matrix pattern. Response was indicated by touching the correct stimulus in the response row.

The computerized matrix task was split into two 120 trial blocks. Six practice trials preceded each block of test trials. Blocks represented one of two spatial conditions: ordered or latin square arrangement of stimulus elements within the matrix. One trial block was administered in each of two testing sessions. Block presentation order was counterbalanced across subjects. One group was presented with simple, spatially correlated matrix problems first. The other group was presented with the more difficult, spatially uncorrelated matrix problems (i.e., latin square arrangement of stimuli) first. Examples of ordered versus latin matrix problems are presented in Figure 1. Total time to complete each block of 120 trials was approximately forty-five minutes.

Match-to-sample (MS)

The MS task was a pattern matching task adapted from the cognitive abilities tests (CAT; Detterman, 1988). The CAT consists of eleven tasks designed to test basic abilities. The MS task in the current

study was modified so that test trials were identical to the first 60 exemplar rows of each 120 trial block of the adapted experimental matrix task. Correspondingly, probe items in the MS task were the missing items from the 60 matrix trials. The MS task was designed to measure speed and accuracy of encoding, discrimination, and response selection/execution processes.

Each trial had seven stimuli (windows); a row of six stimuli and a probe stimulus centered above the row. The image of a spacebar was displayed at the bottom of the screen. Display size was 13.5 cm X 25 cm. There were four practice trials and a minimum of 120 test trials, 60 tested in each session. Incorrect test trials were reinserted, therefore, the total number of test trials was a function of the number of errors.

At task onset, all stimuli appeared as blank grids. When the image of the spacebar was touched, seven patterns appeared; six different patterns in the row and a probe pattern identical to one of the six patterns. The patterns stayed on the screen as long as the bar was held. Each student indicated a match by lifting their finger from the bar and touching the stimulus identical to the probe. Decision time was the amount of time between the onset of the stimulus display and when a subject lifted their finger from the spacebar. Movement time was the amount of time from the finger lift until the subject touched a stimulus in the response row. Computer record was kept of decision and movement time and accuracy on all test trials.

The matching task was divided into two 60 trial blocks with one block administered in each of two testing sessions. Within each session, the MS task was administered following the first sixty trials of the adapted experimental matrix task as follows: matrix task (first sixty trials), matching task (sixty trials), and matrix task (second sixty trials).

Learning (LR)

The LR task was a probed recall, multitrial task which measured speed and accuracy of recalling the positions of novel perceptual stimuli. Each trial began with a row of blank windows (2, 3, 5, 7, or 9) in the lower portion of the screen. A probe window was centered above the row of blank windows. When the subject touched the bar, one stimulus appeared in each blank grid, consecutively, moving from left to right. Presentation time for each stimulus was 1 second. At the end of the presentation, probe stimuli appeared randomly from the set of stimuli to be learned. The testee was to indicate the position in which that stimulus appeared by touching the position on the screen. Testees had 10 seconds to respond correctly.

Five practice trials were presented which contained two stimulus positions to be learned. Test trial blocks contained 3, 5, 7, or 9 stimuli to be learned, respectively. Each test block contained a maximum of 10 trials. If the testee learned the position of 67% of the stimuli in the set in ten trials or less, the number of elements in the set was increased by two. If the testee did not meet the criterion in ten trials or less, the task was terminated. Time, accuracy, and number of blocks administered were recorded.

Tachistoscopic threshold (TT)

The TT task determined the minimum amount of time required for a testee to decide if two windows, i.e., novel perceptual stimuli, were the same or different. Display size measured 16.75 X 10.9 cm. The initial screen had the image of a spacebar at the bottom. Same (left) and different (right) response choices were above and on either side of the spacebar indicated by two patterns which were either the same or different.

When a testee touched the image of the spacebar, a fixation point appeared. After a variable delay two stimuli appeared. A solid blue mask immediately followed the display for a duration of 250 ms. The subject's task was to determine whether the two stimuli which appeared were the same or different. Response was indicated by touching either the pattern for same or the pattern for different. Initial duration of the two stimuli was 17 ms. Duration increased by 17 ms each time an incorrect response was made. Test trials were divided into 20 blocks. Testing was terminated when a testee got 5 consecutive correct trials for twenty blocks or 287 trials were administered, whichever came first. There were three practice trials presented for 50 ms each.

Tachistoscopic threshold was the stimulus duration on the last trial administered. Decision time was the time between when the stimulus was flashed and the subject lifted their finger from the spacebar image. Movement time was the time between when a subject lifted their finger and touched the symbols indicating either same or different. Decision time, movement time, threshold, and number of trial blocks completed were recorded.

Session 1

All students were told that they would be taking a series of cognitive tests to aid in understanding the relationship between problem solving abilities and basic perceptual processes. Subjects were asked to read

a brief description of the study and to sign the consent form if they choose to participate. Students were also asked to sign a release form which gave the investigator permission to obtain their ACT scores from university files. After obtaining informed consent, the SPM was administered followed by the first blocks of the adapted experimental matrix and matching (MS) tasks, respectively.

Session 2

The second testing session consisted of the remaining blocks of the matrix and matching tasks, and two additional basic cognitive tasks (LR & TT). The two additional tasks were designed to measure memory for position and the threshold needed to determine whether two patterns were the same or different (discrimination time), respectively.

Results

The general purpose of the current study was to refine the a previously developed (Andrist & Detterman, 1990) computerized matrix task to independently define and reliably measure the effects of specific perceptual parameters on individual differences in performance on measures of cognitive ability.

Measures of individual differences in cognitive ability included two standardized psychometric tests and a match-to-sample task. Standardized tests were measures of general cognitive ability. They included the composite score for the American College Test (ACT) and number correct on the Raven's Standardized Progressive Matrices (SPM). The ACT is an achievement test; the SPM as a classic test of inductive reasoning. Basic cognitive tests included measures of learning (LR), tachistoscopic threshold (TT), and decision time on a match-to-sample task (MS).

Results are divided into three major sections: 1) basic statistics for the experimental measures were included in a preliminary section, 2) correlation and multiple regression analyses were carried out to determine the role of interstimulus form and amount in the prediction of individual differences in cognitive ability, and 3) correlation and multiple regression analyses were done to evaluate the mediating effect of intrastimulus perceptual structure (individual stimulus complexity) on patterns of individual differences. Analyses focus on the prediction of general cognitive ability from parameters of perceptual structure.

Distributions for all experimental variables were examined for outliers (values > 3 SD from the mean of individual distributions). Six outliers were identified for the adapted experimental task (MX2); six for the match-to-sample task (MS). Outliers were distributed across both groups of presentation order and were generally found in the initial test condition which was administered. One outlier was identified for the Raven's Standardized Progressive Matrices (SPM), three for the learning task (LR), and five for the tachistoscopic threshold task (TT). All analyses were done with and without outliers. Patterns of results were similar for all analyses involving comparison of mean differences in performance. Individual difference analyses, on the other hand, tended to be more sensitive to outliers. The six outliers for the experimental matrix task were deleted from all analyses. Other outliers were deleted only from specific analyses involving that measure. Analyses include results for 94 students on the experimental matrix and SPM tasks, 90 on the MS and LR tasks, 83 on the TT task, and 64 on the ACT.

Preliminary Analyses

Descriptive statistics

Means and standard deviations were computed for all experimental measures without outliers. Mean percent correct on the experimental matrix task was 74% (SD = 11%) with mean time to complete each problem 16.31 (SD = 6.43) seconds. Mean number correct on the SPM was 48 (SD = 5.8) out of 60 total problems with mean time to complete all 60 problems recorded at 21.00 (SD = 7.34) minutes. Mean score on the ACT composite was 18 (SD = 6.6). SPM and ACT scores without outliers were not different than those reported for the total group. Scores for tachistoscopic threshold (TT) and decision time on the match-to-sample task (MS) were .18 (SD = .12) and 2.50 (SD = .48) seconds, respectively. Percent correct on the learning task (LR) was 54% (SD = 10%). Means (SD) for the MS and LR tasks were similar to previously reported means in a normally distributed high school sample (Detterman, 1984). Mean tachistoscopic threshold, however, was much higher than the previously reported threshold for the high school sample, .04 (SD = .03) seconds. Differences may reflect the older mean age of the current sample.

Reliabilities

Reliabilities were reported for all experimental measures included in the current study. Split-half reliabilities for the experimental matrix task were calculated using an alternate-item procedure. Corrected Spearman-Brown split-half reliabilities for percent correct, solution time and the within-subject standard deviation of solution time were .96, .99, and .98, respectively. Split-half reliabilities for the match-to-sample task were calculated using a first-second half procedure. Corrected split-half reliabilities for decision time and the within subject standard deviation of decision time were .93 and .86, respectively. The corrected Spearman-Brown split-half reliability for tachistoscopic threshold was .72.

Reported test-retest reliabilities on the Raven's SPM for testees under 40 years old ranged from .88 to .93 (Raven, Court, & Raven, 1983). Reported split-half reliability for percent correct on the learning task in the high school sample of 141 seniors was .97 (Detterman, 1984). In sum, all experimental measures used in the current study were moderately to highly reliable ($r_{1 \times 2} = .72$ to .99).

General validity of the experimental matrix task

General external validity of the adapted experimental matrix task was tested by correlating the adapted matrix task with a set of independent measures of cognitive ability. Measures included both standardized tests of general ability such as number correct on the Raven's Standardized Progressive Matrices (SPM) and the ACT comprehensive score and more basic cognitive measures such as learning (LR), tachistoscopic threshold (TT), and decision time on the match-to-sample task (MS). Correlations between percent correct on the adapted matrix task and accuracy on the SPM, ACT, and LR tasks were expected to be high with the highest correlations expected between accuracy on the adapted matrix task and SPM. Significant correlations with more traditional measures of encoding and discrimination such as tachistoscopic threshold (TT) and decision time on the MS task were not expected to be high.

Significant one-tailed correlations were identified between overall percent correct on the adapted matrix task and measures of accuracy on the SPM, $r = .65$, $p < .001$, ACT, $r = .33$, $p < .01$, and LR, $r = .45$, $p < .001$ tasks. Correlations between accuracy on the SPM and accuracy on the LR and ACT were .40 and .44, respectively, both p 's $< .001$. Correlations were not significant between percent correct on the adapted matrix task and either tachistoscopic threshold (TT) or decision time on the MS task.

Conversely, time on the adapted matrix task was related to both TT, $r = .28$, $p < .01$ and decision time on the MS task, $r = .45$, $p < .001$ but not to measures of accuracy on the SPM, ACT, or LR tasks. Again, patterns of correlations between overall time on the experimental matrix task and measures of cognitive ability were similar to patterns of correlations between time on the Raven's SPM and measures of cognitive ability. Time on the matrix task and time on the SPM were intercorrelated, $r = .59$, $p < .001$.

In sum, patterns of correlations between both time and accuracy on the experimental matrix task and other cognitive measures were similar to patterns of correlations identified for time and accuracy on the Raven's SPM. Correlations supported the validity of the adapted experimental matrix task as a measure of general cognitive ability which tapped processes similar to those measured by the SPM. A summary table of intercorrelations between experimental measures is presented in Table 2.

Insert Table 2 about here

Prediction of Individual Differences in Cognitive Ability:

The Role of Interstimulus Form versus Amount

Two components of interstimulus perceptual structure were defined and measured on the adapted experimental matrix task: form and amount. The current set of analyses tested the relationship between operationally defined parameters of interstimulus form and amount and individual differences in cognitive ability.

Patterns of individual differences between interstimulus form and amount and measures of cognitive ability were investigated as follows: 1) correlations between levels of the adapted experimental matrix task and the five measures of cognitive ability were computed in order to identify important relationships between form and amount, 2) hierarchical multiple regression analyses predicting accuracy of performance on both the SPM and ACT as a function of increasing interstimulus complexity (decreasing form and increasing amount) were computed to determine the independent contribution of each component in the prediction of general cognitive ability, and 3) two stepwise multiple regression analyses were conducted in order to identify the best predictors of accuracy on the SPM and ACT.

It was hypothesized that interstimulus dimensional form would be highly related to individual differences in performance on standardized measures of general cognitive ability such as accuracy on tests of reasoning (SPM) and achievement (ACT).

Correlations

Correlations between both time and accuracy on the adapted matrix task and independent measures of cognitive ability such as accuracy on the SPM and ACT were computed across changing levels of interstimulus form and amount. Significant one-tailed correlations were identified for form and amount. Significant differences between the magnitude of the correlations were identified with follow-up z-tests.

Correlations between percent correct on the adapted matrix task and accuracy on the SPM and the composite score of the ACT, ranged from .06 to .65 with significant increases in the magnitude of correlation associated with form of dimensional structure on all three measures. A follow-up z-test was conducted to test the differences in level of correlation. Increases in correlation for the two measures ranged from .38 to .46, both z 's ≤ -2.52 , both p 's $< .05$ as dimensional form decreased.

A significant correlation between solution time on initial levels of the matrix task and the SPM task was identified, $r = -.31$, $p < .01$. An increase in the magnitude of correlation between solution time on the matrix task and accuracy on the SPM of .62 was associated with decreases in dimensional form, $z = -3.98$, $p < .001$. No significant increases in the magnitude of correlation between solution time on the experimental matrix task were associated with increases in dimensional amount or the ACT composite score.

In sum, decreasing interstimulus dimensional form was significantly related to general cognitive ability as measured by accuracy on the SPM and ACT.

Hierarchical multiple regression analyses: Independent contributions of interstimulus form and amount

The independent contribution of interstimulus form and amount relationship in the prediction of individual differences in general cognitive ability was investigated by predicting accuracy on the Raven's Standard Progressive Matrices (SPM) and American College Test (ACT) from both percent correct and solution time on individual levels of interstimulus structure. A total of 10 levels of interstimulus structure representing two levels of amount were included in the current set of analyses. The first level of dimensional amount (2 dimensions changing) contained four levels of dimensional form (2x2 factorial combination of

dimension X level of correlation); the second level of amount (3 dimensions changing) contained six levels of form (3x2 factorial combination of dimension X level of correlation).

Three hierarchical multiple regression equations were generated for each dependent. The first two equations tested the effects of decreasing form on general cognitive ability within the first and second levels of amount, respectively. Decreasing levels of dimensional form (increased complexity) were entered into each hierarchical multiple regression equation on successive steps. Four levels of form were entered into the hierarchical equation corresponding to the first level of amount; six levels of form were entered into the hierarchical equation corresponding to the second level of amount. The third equation tested the independent effects of amount on the prediction of individual differences in general ability by entering levels of amount on successive steps of the analyses. The third analysis was conducted as follows: The four levels of form corresponding to the first level of amount were entered on step one of the analyses. The six levels of form corresponding to the second level of amount were then entered using a stepwise procedure. In the stepwise procedure the variable which accounts for the most variance is entered first. Next, variables are entered one at a time in decreasing order of importance until all variables which add a significant amount of variance to the prediction of the dependent are entered. Analyses were reported separately for the two dependent measures.

Raven's Standard Progressive Matrices (SPM). The role of changing interstimulus form in the prediction of accuracy on the SPM was investigated separately within each level of amount. Hierarchical multiple regression analyses corresponding to the first and second levels of amount were conducted as described above. Significant increases in the prediction of performance on the SPM were associated with the addition of the first three levels of form on the initial level of amount (2 dimensions), with the squared multiple- R increasing from .09, $F(2,91) = 4.49$, $p < .01$ to .53, $F(6,87) = 16.32$, $p < .001$ as dimensional form decreased. Results for increased amount (3 dimensions) were similar to results from the first level of amount tested, with significant increases in the prediction of accuracy on the SPM identified with the addition of each of the first four levels of form, R^2 increasing from .15, $F(2,91) = 7.78$, $p < .001$ to .53, $F(8,85) = 12.08$, $p < .001$ for decreasing levels of form.

The independent contribution of amount in the prediction of individual differences on the SPM was tested by entering levels of amount on two successive steps in the multiple regression analyses as described

above. The first level of amount accounted for 53% of the variance in accuracy on the SPM, $F(8,85) = 12.15$, $p < .001$. A significant increase in the predictability of accuracy on the SPM was associated with increased amount, percent correct on moderately complex (partially correlated) matrix problems adding 3% to the prediction, $F(9,84) = 5.58$, $p < .05$.

American College Test (ACT). Patterns of predictability for the ACT were assessed separately for each level of amount using the first two hierarchical multiple regression analyses as described above. A significant increase in the prediction of accuracy on the ACT was associated with decreases in form on the initial level of amount tested. The squared multiple-R increased from .01 on the first level to .25, $F(8,55) = 2.25$, $p < .05$, on the fourth level. Increases in variance associated with decreased form were 3%, 13% and 7% for each level entered, respectively. Only the increase of 13%, $F(6,57) = 4.68$, $p < .01$ associated with decreased form on complex (uncorrelated) matrix problems was significant, however. Results for the second level of amount reflected similar findings, with significant increases in the prediction of accuracy on the ACT associated with decreases in form, R^2 increasing from .11, $F(2,61) = 3.73$, $p < .05$ to .35, $F(12,51) = 2.25$, $p < .05$ as form decreased. A significant increase was only identified for the fifth level of form entered (complex structure among dimensions), $R^2 = .14$, $F(10,53) = 2.50$, $p < .05$, however.

The independent contribution of interstimulus amount on the prediction of performance on the ACT was tested by entering levels of amount on successive steps of the multiple regression equation as described above. The first level of amount accounted for 25% of the variance in accuracy on the ACT, $F(8,55) = 2.25$, $p < .05$. Significant predictability for increased levels of amount were associated with solution time on two the simplest levels of form contributing 12%, $F(9,54) = 10.72$, $p < .01$ and 6%, $F(10,53) = 5.76$, $p < .05$ to the prediction of accuracy on the ACT, respectively.

In sum, hierarchical multiple regression analyses indicated that the relationship between performance on the adapted experimental matrix task and general cognitive ability as measured on both the SPM and ACT were a function of both interstimulus dimensional form and amount with decreasing form the strongest predictor of individual differences in cognitive ability. The prediction of accuracy on the SPM increased systematically across decreasing levels of form on the adapted matrix task. Increased prediction of the ACT were only associated with the more complex levels of form. Results generally support experimental

hypotheses with 53% and 25% of the variance on the SPM and ACT tasks predicted by decreases in dimensional form and an additional 3% and 18% predicted by increases in dimensional amount, respectively. Figure 2 shows increases in the prediction of performance on the SPM and ACT tasks as a function of increasing interstimulus complexity (decreasing dimensional form and increasing amount).

Insert Figure 2 about here

Stepwise multiple regression analyses: Identification of the best predictors of performance on the SPM and ACT

Two multiple regression analyses were conducted to determine whether higher levels of interstimulus form and amount were the best predictors of accuracy on the Raven's Standard Progressive Matrices (SPM) and American College Test (ACT), respectively. Both percent correct and solution time from all 12 levels of the experimental task were entered into each multiple regression equation using a stepwise procedure. Analyses were reported separately for the SPM and ACT, respectively.

Raven's Standard Progressive Matrices (SPM). Three variables entered into the stepwise solution in the prediction of accuracy on the SPM: two measuring percent correct on complex (uncorrelated) levels of dimensional form and one measuring solution time on a simple (correlated) level, in that order. Percent correct on the two uncorrelated levels of form predicted 50% of the variance in the SPM, $F(2,91) = 44.88$, $p < .001$. The increase in variance associated with solution time on the highly correlated level of form was 4%, $F(3,90) = 7.65$, $p < .01$. Total variance accounted for by the three variables was 54%, $F(3,90) = 34.65$, $p < .001$ as compared to 64%, $F(24,69) = 5.11$, $p < .001$ when all 24 variables were entered.

American College Test (ACT). Five variables entered into the stepwise solution for performance on the ACT. The single best predictor of the ACT task was solution time on the most complex (uncorrelated) level of the matrix task, $R^2 = .14$, $F(1,62) = 10.29$, $p < .001$. Percent correct on the two simplest (highly correlated) levels of form entered the equation next, accounting for 8%, $F(2,61) = 6.59$ and 7%, $F(3,60) = 5.74$ of the variance, both p 's $< .05$. The last two variables to enter the equation were, again, solution time measures on uncorrelated levels of the matrix task, accounting for an additional 7%, $F(4,59) = 8.43$ and 8%, $F(5,58) = 9.29$, both p 's $< .01$. Total variance accounted for by the five matrix task variables in the prediction of accuracy on the ACT was $R^2 = .44$ with $F(5,58) = 9.29$, $p < .001$ as compared to an $R^2 = .59$, $F(24,39) = 2.33$, $p < .01$

when all 24 variables were entered into the equation. The absolute increase in variance accounted for by the set of 24 variables was not significant.

In order to test the independence of each set of variables in the prediction of their respective dependents, analyses were repeated. First, the respective sets were reversed, i.e., the five variables which predicted performance on the ACT were used to predict performance on the SPM and vice versa. The set of five variables including time on uncorrelated problems and percent correct on correlated problems predicted 18% of the variance in performance on the SPM as compared to 59% from the set including three variables representing percent correct on uncorrelated problems and time on simple problems. When the sets were reversed, 12% of the variance in the ACT was predicted as compared to the 44% predicted by the original set. Follow-up z-tests indicated that differences between the absolute amount of variance predicted for both the SPM and ACT when the respective sets of variables were switched were significant, both z 's < -2.02 , both p 's $< .05$.

In sum, results supported general experimental hypotheses with performance on uncorrelated matrix problems predicting individual differences in general cognitive ability as measured by accuracy on the SPM and ACT tasks. Performance on the SPM was predicted by accuracy on complex matrix problems and time on simple problems. The ACT, on the other hand, was predicted by time on complex problems and accuracy on simple problems.

The Relationship between Interstimulus and Intra-stimulus Structure: The Role of Stimulus Complexity

Interstimulus structure refers to the complexity of relationships among stimuli in the matrix. Intra-stimulus structure refers to the complexity of individual stimulus items. Although the study of individual stimulus complexity has occupied much of the perceptual literature, the relationship between intra-stimulus complexity and interstimulus complexity has been virtually ignored. The relationship between individual differences in the performance on adapted matrix task as a function of intra-stimulus structure was tested in two sets of multiple regression analyses. The first set determined the role of increased stimulus complexity on overall prediction of general cognitive ability. The second set of analyses examined the role of increased stimulus complexity on individual levels of amount and form.

Overall role of increasing intrastimulus structure on the prediction of the general cognitive ability. Two hierarchical multiple regression analyses were conducted with accuracy on the SPM and ACT each as dependent variables in order to determine the overall effect of increased stimulus complexity on the prediction of general cognitive ability. All 12 levels of percent correct and solution time for simple stimuli were entered on the first step of the analyses using a stepwise procedure. Next, in order to determine if increased stimulus complexity added to the prediction of general cognitive ability, all 12 levels of percent correct and solution time for complex stimuli were added into the equation using a stepwise procedure.

Five and three variables from the simple set were entered in each multiple regression equation accounting for 57%, $F(5,88) = 23.05$ and 31%, $F(3,60) = 8.96$ both p 's $< .001$ in the prediction of accuracy on the SPM and ACT, respectively. Results indicated that percent correct on uncorrelated problems and time on correlated problems were the best predictors of performance on the SPM. Time on uncorrelated problems and percent correct on correlated problems were the best predictors of performance on the ACT. Results were consistent with overall analyses reported above. Increased stimulus difficulty added 4% and 11% to the amount of variance accounted for by the SPM and ACT, respectively increasing the respective squared multiple- R 's to .61, $F(7,86) = 19.12$ and .42, $F(5,58) = 8.25$, both p 's $< .001$.

Role of increased intrastimulus structure on individual levels of amount and form. A series of hierarchical multiple regression analyses were conducted in order to determine the amount of variance accounted for by changes in stimulus complexity on individual levels of the adapted matrix task. Regressions were conducted, in turn, with accuracy on the SPM and ACT as dependent measures. Levels of stimulus complexity were entered on two successive steps across all levels of the matrix task for each dependent measure.

Increases in the predictability of percent correct on the adapted matrix task were associated with accuracy on both the SPM and ACT tasks with changes in stimulus complexity accounting for between 5 and 10 percent of the variance, all p 's $< .05$ on both simple and uncorrelated matrix problems. Significant increases in predictability of performance on the SPM and ACT tasks across levels of stimulus complexity were also associated with solution time on the most complex (uncorrelated) levels of the matrix task. Increases in the prediction of performance on the SPM task, ranged from .07 to .21 for all measures of time associated with uncorrelated trials, all p 's $< .01$.

In sum, although the amount of variance associated with the matrix task increased as stimulus complexity increased, the absolute amount of variance accounted for in the prediction of either the SPM and ACT tasks did not increase significantly. Analyses of individual levels of the matrix task indicated that increases in the predictability of percent correct on the adapted matrix task associated with increased stimulus complexity were stable across levels of amount and form on both the SPM and ACT with increases in variance between 5-10%. Changes in the predictability of solution time associated with increased stimulus difficulty, on the other hand, were only identified for uncorrelated matrix problems. Increases in stimulus difficulty associated with solution on uncorrelated problems indicated an interaction between complex (highly uncorrelated) matrix problems and individual differences in encoding and discrimination time with more difficult stimuli having an increasing effect on response time on highly uncorrelated levels of the matrix task.

Discussion

The general purpose of the current study was to adapt a previously designed computerized matrix task in order to independently define and reliably measure the role of specific components of interstimulus dimensional structure in the prediction of individual differences in cognitive ability. Two parameters of interstimulus structure were operationally defined and tested: form and amount. Within interstimulus form, separate components of spatial and object dimensional structure were also defined and tested.

Preliminary results indicated that the experimental task was a highly reliable and valid measure of general cognitive ability which tapped processes similar to those measured by the Raven's Standardized Progressive Matrices (SPM₄). Tests of mean differences in performance on the adapted matrix task indicated that defined parameters of interstimulus dimensional form and amount both had the anticipated effects on matrix task performance with mean accuracy on matrix problems decreasing as the level of interstimulus structure increased. Solution time on the matrix task was confounded with practice effects, however, decreasing as the level of interstimulus structure increased. Effects were attributed to the fact that matrix problems were administered in order of increasing difficulty, i.e., increasing interstimulus dimensional structure. Results indicate that measures of time are extremely sensitive to practice effects while measures of accuracy do not appear to be affected by practice.

Analyses also indicated that parameters of interstimulus amount and form had differential effects on matrix task performance. Mean differences in accuracy associated with increases in interstimulus amount decreased in a very systematic, additive way. Changes in form affected mean differences in performance on the matrix task in a nonadditive way, however, with exponential decreases in accuracy observed as form decreased. Types of form (spatial versus object dimensions), although not equivalent, did not interact with each other. Both measures of form also had similar effects on amount of matrix structure. Results were interpreted as evidence that operationally defined parameters of interstimulus amount and form tapped separate measures of interstimulus structure. Results also indicated that spatial and object dimensional structure were both measures of interstimulus dimensional form with stronger effects on mean matrix task performance associated with object structure.

It was hypothesized that changing interstimulus amount and form would be highly sensitive to measures of individual differences in general ability. Form, as the relational component of interstimulus matrix structure was expected to be the most highly predictive measure of individual differences in mental ability. Changes in amount, as the quantitative measure of interstimulus structure, were expected to be more highly related to time on the matrix task and time dependent measures of encoding and discrimination. Interstimulus amount was also expected to mediate the relationship between more complex levels of interstimulus form and measures of learning, reasoning, and achievement.

General experimental hypotheses were supported with performance on the adapted matrix task predicting general cognitive ability as a function of both interstimulus dimensional form and amount. Decreasing form was the strongest predictor of individual differences in cognitive ability. Performance on the SPM was predicted by accuracy on complex matrix problems. The ACT, on the other hand, was predicted by time on complex problems and accuracy on simple problems.

Differential relationships between components of interstimulus dimensional structure and measures of general cognitive ability were very enlightening. Performance on the ACT task was more sensitive to measures of both time and quantity than the SPM task. The best predictors of individual differences in performance on the ACT task were measures of solution time on the matrix task. Individual differences in performance on the SPM, on the other hand, were predicted primarily by accuracy on uncorrelated levels of

form. Changes in interstimulus amount on adapted matrix task had little or no effect on SPM performance. Proportions of variance accounted for associated with form versus amount in the prediction of performance on each measure of general ability were also informative with 53% and 25% of the variance on the SPM and ACT tasks predicted by decreases in dimensional form and an additional 3% and 18% predicted by increases in dimensional amount, respectively. Results indicate that the SPM task was more strongly related to measures of form and the ACT task was related to both amount and form. The fact that the SPM is more strongly related to form comes as no surprise, since both the operational definition for form and the SPM are based on Spearman's model of cognitive processing. The fact that the adapted matrix task predicts both measures of general ability equally well, but predictions are based on different measures is very intriguing, and may reflect the classic difference between measures of fluid and crystallized intelligence with fluid intelligence more dependent on measures of form and crystallized intelligence more dependent on amount.

As the quantitative component, interstimulus amount was hypothesized to measure processes similar to the process of 'apprehension' described by Spearman (1923) in his model of cognitive processing and, as such, to be highly sensitive to measures of encoding and discrimination. Interstimulus form, on the other hand, was hypothesized to measure the 'eduction of relations and correlates' or the component of cognitive processing which Spearman identified as the most important predictor of individual differences in ability.

Since the SPM was constructed to measure Spearman's model of cognitive processing, the strong relationship between form and performance on the SPM seems to indicate that the changing dimensional form is highly related to what Spearman termed 'eduction of correlates'. Performance on the ACT, on the other hand, is also heavily influenced by the quantitative component of perceptual structure and measures of time. Results support the experimental hypothesis that individual differences in cognitive ability are a function of interstimulus dimensional structure, with changes in interstimulus form highly related to performance on the SPM.

Although on one level 'task specific' variance could be an explanation for the increased relationship between the SPM and accuracy on the form, the type of task specific variance must be considered. If differences in variance accounted for were related to task specific demands such as superficial similarity of task format and/or basic demands of stimulus encoding and matching processes, then why would the proportion

of variance attributed to interstimulus amount be so much higher for the ACT task than for the SPM task?

This is an important question which needs to be pursued in further studies.

Stimulus complexity was also expected to interact with both interstimulus form and amount with stronger performance deficits associated with more complex stimuli as levels of interstimulus complexity increased. Again, general predictions were supported with changes in the predictability of solution time associated with increased stimulus difficulty on the matrix task in more complex (uncorrelated) matrix problems. Changes in stimulus complexity did not affect performance on simple matrix problems. Increases in stimulus complexity associated with solution on uncorrelated problems seems to indicate an interaction between complex matrix problems and individual differences in encoding and discrimination time with more complex stimuli having an increasing effect on response time in highly complex (uncorrelated) matrix problems. The larger mediating effects of stimulus complexity on uncorrelated problems seems to indicate that encoding, discrimination, and response selection/execution times play a larger role in the accuracy of uncorrelated matrix problems than they play in simple (correlated) matrix problems.

In sum, the purpose of the current research was to investigate the relationship between varying degrees of perceptual structure and individual differences in cognitive ability. An adapted computerized matrix task was constructed and tested using a structural model of inductive reasoning. The current structural model was based on one proposed by Royer (1978) which argued for the important role of complex 'correlational structure' in the predication of individual differences in intelligence. Parallel's were drawn between Royer's structural model and Spearman's qualitative model of cognitive processing in the prediction of individual differences in cognitive ability through changing levels of perceptual structure.

The study tested the relationship among parameters of intrastimulus structure, interstimulus structure, and individual differences in cognitive ability. The task was identified as a reliable and valid predictor of individual differences in general ability. Results indicated that changing dimensional structure between stimuli was an important factor in the prediction of individual differences in intelligence. Parameters of interstimulus form and amount were also identified as independent predictors of individual differences in mental ability. Interstimulus form was the most highly related to individual differences in general cognitive

ability. No difference in the magnitude of the prediction was identified for the two measures of general ability. Measures of general ability, i.e., SPM versus ACT, were predicted by different parameters of the adapted matrix task, however. The SPM was predicted by percent correct on complex (uncorrelated) problems of the matrix task and solution time on simple (correlated) problems of the matrix task. The ACT, on the other hand, was predicted by solution time on highly uncorrelated levels of the matrix task and percent correct on correlated levels. Results also indicated that interstimulus form was a better predictor of performance on the SPM; amount, on the other hand, was a better predictor of the ACT. It was suggested that the differential predictive validity of measures of percent correct versus solution time and form versus amount for the SPM and ACT, respectively, may reflect the classic distinction between measures of fluid and crystallized intelligence (Cattell, 1971). Fluid measures of ability are highly related to measures of inductive reasoning; crystallized measures of ability have generally been defined in terms of past knowledge. The current study suggests distinctions between these two types of measures in terms of basic processing components. The distinction may be an important link between psychometric and information processing measures of intelligence.

Individual difference analyses indicated that measures of amount and stimulus complexity had similar effects on performance and that form had differential effects. Results support the experimental hypothesis that interstimulus amount and intrastimulus (individual stimulus) complexity are both quantitative measures which reflect the information load of the matrix and stimuli, respectively. Interstimulus form, on the other hand, seems to be measuring a process more closely associated with measures of learning or what has been described by Spearman as the 'education of relations and correlates'. This process, rather than being a complex cognitive process based on 'higher order processing' has been defined, in the current study, as a basic process based on the systematic manipulation of relationships between dimensions in a matrix. Royer's (1978) structural model of intelligence was supported.

The classic measures of stimulus encoding and discrimination were sensitive to quantitative measures of both individual stimulus and matrix information. The relational component of form extends the same-different comparison to ask, 'How are these two stimuli different?' The current model is an attempt to bridge the gap between 'perceptual' and 'conceptual' processing by operationally defined processes on an inductive reasoning task in terms of perceptual structure.

In conclusion, changing dimensional relationships between stimuli were identified as important, independent predictors of individual differences in general cognitive ability. Results are interpreted as evidence of the importance of perceptual structure in the prediction of individual differences in intelligence. Results are consistent with Spearman's qualitative model of mental ability.

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Table 1: Means (SD) for Stimulus Complexity Parameters for the Simple and Complex Stimulus Sets of the Experimental Task

	Number of Squares Filled	Number of Adjacencies	Equivalent Set Size	Sub- symmetry	Number of Turns
Simple Set	6.0 (1.6)	4.8 (2.3)	4.9 (1.9)	184.9 (110.0)	7.3 (1.8)
Complex Set	6.0 (1.6)	2.9 (2.6)	5.0 (2.0)	118.3 (50.9)	14.2 (2.7)

Table 2. Intercorrelations between the Adapted Experimental Matrix Task and Measures of Cognitive Ability

	1.	2.	3.	4.	5.	6.	7.	8.
1. Matrix Task - Correct	1.00							
2. Matrix Task - Time	.37**	1.00						
3. Learning - Correct	.45**	-.06	1.00					
4. Matching DT	-.20	.45**	-.36**	1.00				
5. Tachistoscopic Thres.	-.26*	.28*	-.25	.32**	1.00			
6. ACT Score	.33*	.11	.32*	-.10	.17	1.00		
7. Raven's Correct	.65**	.08	.40**	-.21	.12	.44**	1.00	
8. Raven's Time	.29*	.59**	-.06	.22	.31*	.17	.32**	1.00

Minimum pairwise N of cases: 58 1-tailed Signif: * - .01 ** - .001

Figure 1: Twelve Levels of Interstimulus Structure.

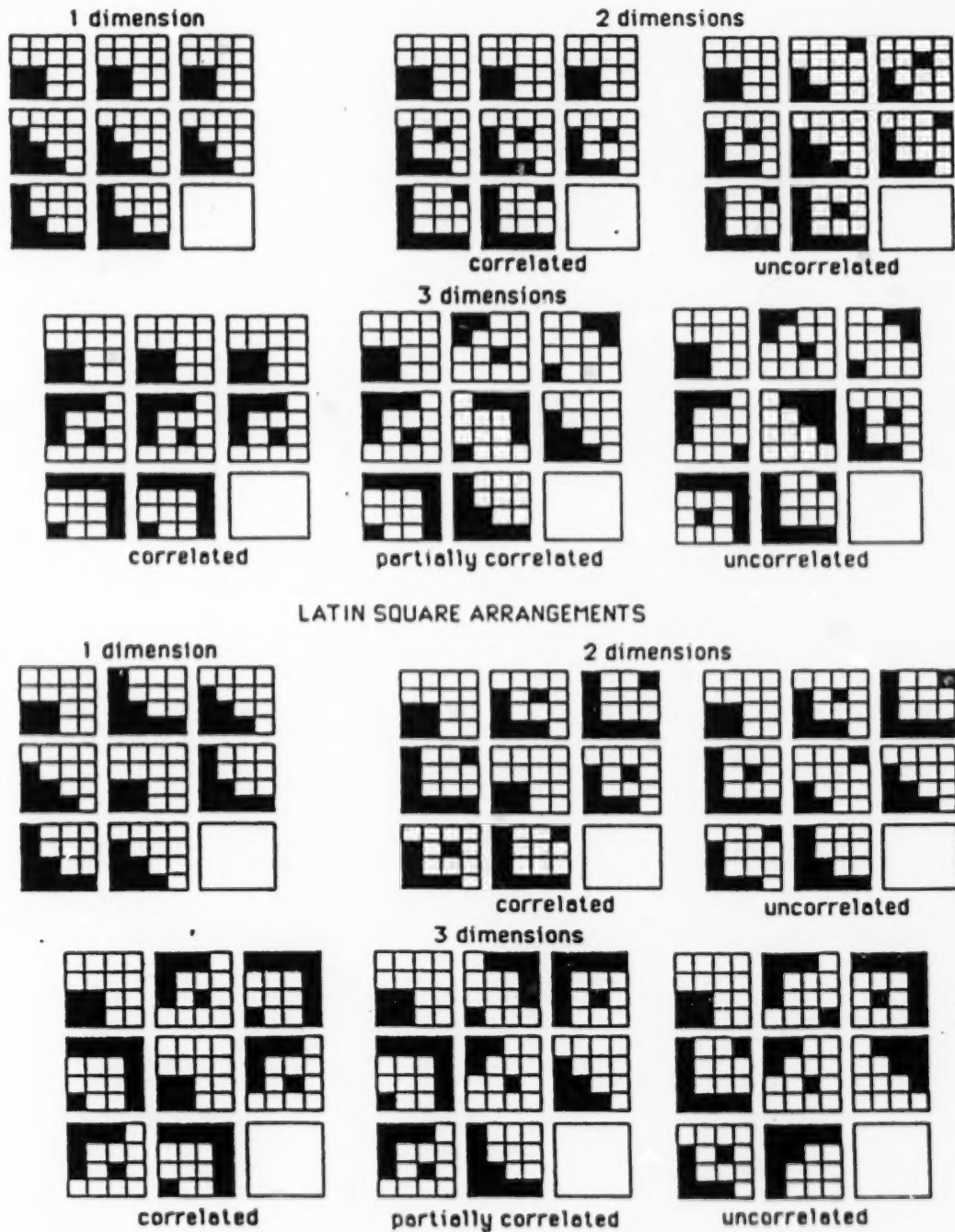


Figure 2: Prediction of the SPM and ACT as a Function of Interstimulus Form and Amount

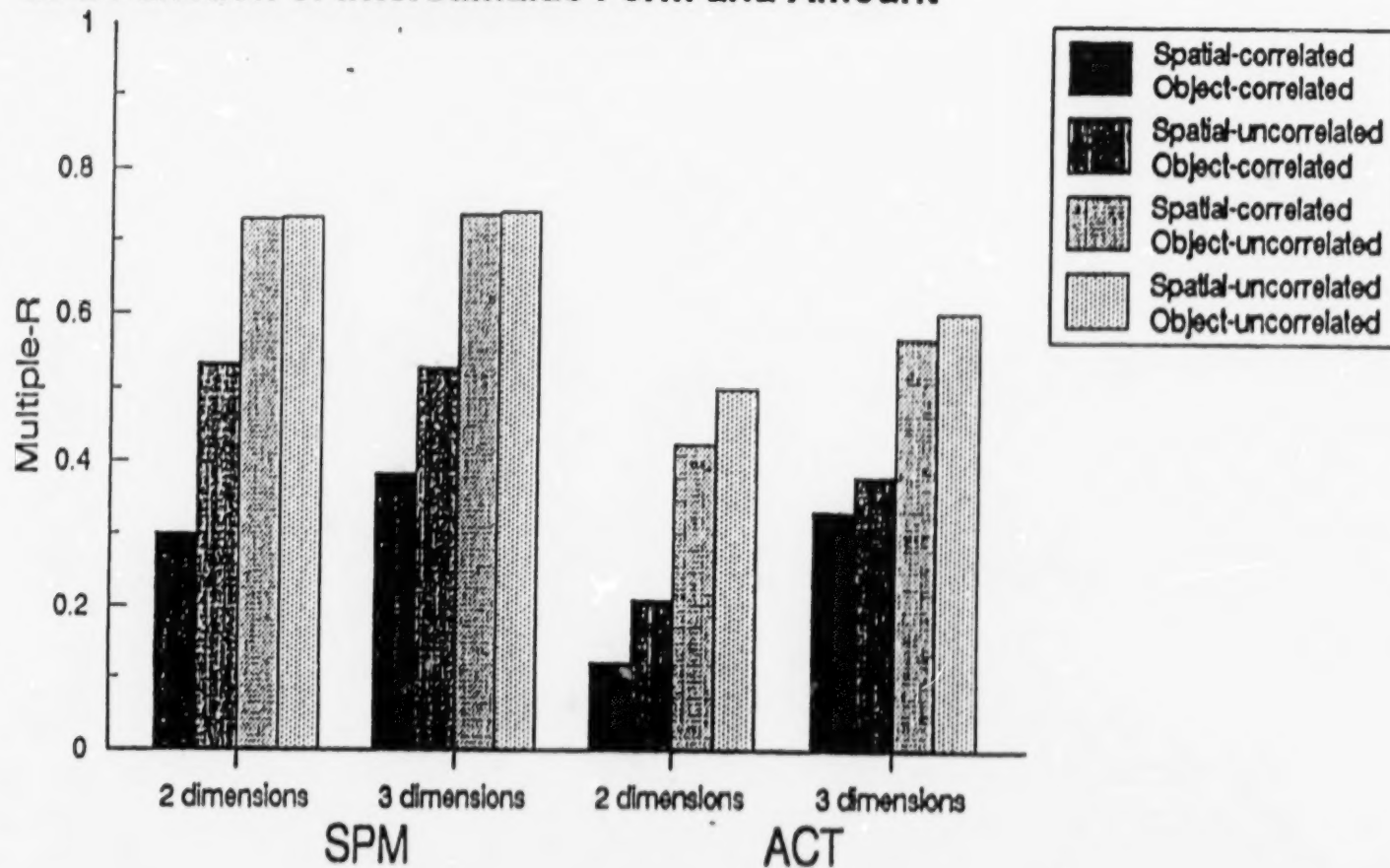
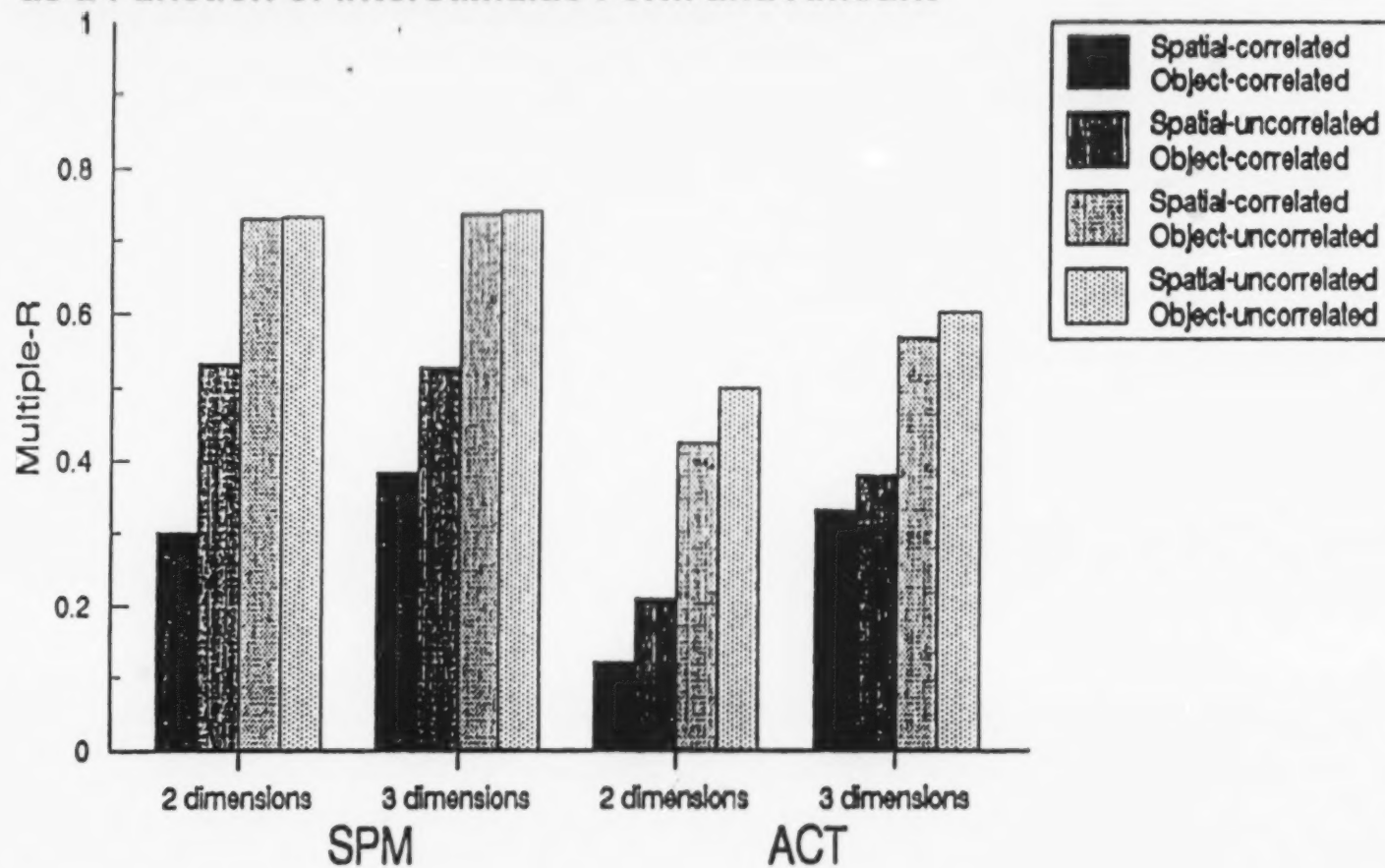
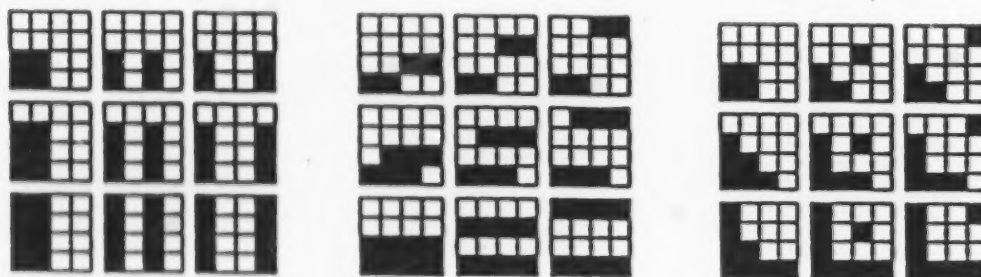


Figure 3: Prediction of the SPM and ACT as a Function of Interstimulus Form and Amount

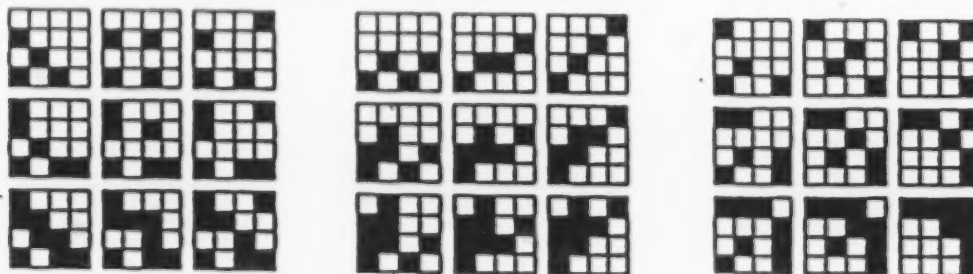


Appendix A: Mean Difficulty Ratings for Simple and Complex Stimulus Sets for the Adapted Experimental Matrix Task

Easy set: Mean difficulty rating = $-.76$ (SD = $-.35$)



Hard set: Mean difficulty rating = 1.39 (SD = $.49$)



Only the first nine items from each set are shown.
Remaining items include rotations of shown items at 90° and 180° .